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UTILIZING OFDM AS A SPECIFIC CASE OF SECOND ORDER KALMAN FILTERING ALGORITHM

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ABSTRACT

Orthogonal frequency division multiplexing had achieved a good deal of significance due to the high data rate of its transmitting capacity, vigour against frequency selective fading channels. The aim of the study is to Utilizing of OFDM as a Specific Case of Second Order Kalman Filtering Algorithm. In this paper a Kalman smoother is actually suggested, which uses more measurements and it is a lot more precise in comparison to the Kalman filtering. It'll be proven that the recommended method provides channel mean square error (MSE) is actually near to that of the perfect minimum mean square error (MMSE) Wiener filter. For data detection, a low complexity MMSE along with decision feedback equalizer (DFE) algorithm is actually utilized to control intercarrier interference (ICI). The computational price of this new algorithm is on exactly the same order as current channel estimation algorithms.

Keywords: *Channel, OFDM, networks, Second order, Kalman Filtering algorithm, etc*.

1. INTRODUCTION

Many advanced communication technologies, such as orthogonal frequency division multiplexing (OFDM) modulations, have recently become available. OFDM has been used or proposed in a variety of applications, including satellite and terrestrial digital audio broadcasting (DAB), digital terrestrial television broadcasting (DVB), broadband indoor wireless systems, asymmetric digital subscriber line (ADSL) for high bit-frequency digital subscriber services on twisted pair channels, and fixed broadband wireless access. OFDM systems have the benefit of being immune to multipath fading and impulsive noise. Equalization is greatly easier in OFDM since the individual subcarrier signal spectrum is frequency-flat rather than frequency-selective fading. For general military applications as well as software defined radio, the requirement to identify OFDM signals from single carriers has become apparent. The subject of modulation categorization has been explored for decades, with analogue and digital modulation types being considered. However, in comparison to studies on modulation classification for single carriers, modulation classification for these developing modulation schemes has received far less attention. We constructed a classifier based on a statistical test thanks to the well acknowledged fact that the OFDM is asymptotically Gaussian. The suggested Gaussianity test is based on samples of the received signal's empirical distribution function (EDF). It's actually a hypothesis test problem, with the H1 hypothesis (non-Gaussian process) limited to single carrier modulation and the H0 hypothesis (Gaussian process) allocated to OFDM signals. Aside from differentiating an OFDM signal from a single carrier, certain important OFDM signal properties need be collected for further processing. These parameters include, but are not limited to, the number of subcarriers, the duration of OFDM symbols, and the duration of the cyclic prefix (CP), among others. With those characteristics in hand, traditional modulation classification algorithms may be used to identify the linear modulation type on each OFDM subcarrier.

1.1 Orthogonal Frequency Division Multiplexing (OFDM)

Orthogonal Frequency Division Multiplexing (OFDM) method, that is a unique Multicarrier Modulation (MCM) technique, has been demonstrated for a high speed data communication. OFDM is actually the specific case in multi carrier transmission strategy, in which a single data stream is actually transmitted over a selection of lower frequency sub carriers. OFDM method has been generally implemented in high speed digital communications to boost the robustness against frequency selective fading. The fundamental concept of OFDM is actually to split a high speed data stream directly into a selection of lower frequency streams which are transmitted together over a variety of subcarriers.

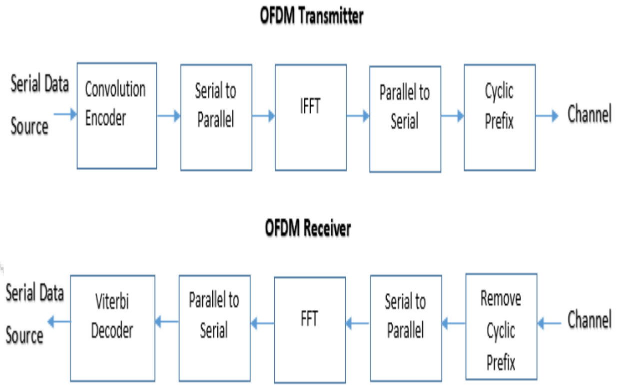

Figure 1: Block diagram of OFDM System

1.2 Framework of OFDM System

OFDM is actually a specific case of multicarrier transmission, in which a signal data Stream is actually transmitted over a selection of lower frequency sub carriers. Among the primary reasons to utilize OFDM is increasing the strength against frequency selective fading or may be narrow band interference. In a single carrier process, a fading or maybe interference is able to result in the whole domain to fail, however in multi carrier system, just a small proportion of the sub carriers will likely be impacted. Error correction coding could likewise be utilized to identify the incorrect sub carriers and correct them. In a typical parallel data system, the entire signal frequency band is split into N non overlapping frequency sub channels. Each sub channel is actually modulated with a distinct symbol and then the N sub channels are actually frequency multiplexed. It's a good idea to stay away from spectral overlap of channels to get rid of inter channel interference. Nevertheless, this leads to ineffective use of the accessible spectrum. in order to stay away from the ineffective spectral use parallel information transform and FDM based overlapped sub channels are utilized to ensure that each sub band carrying a signalling charge b is actually spaced b apart in frequency to stay away from the usage of high speed equalization circuits as well as to fight impulsive noise as well as multipath distortion.

1.3 Application of OFDM System

The OFDM has created in systems that are different for large band digital communications, used in uses like digital televisions, sound broadcasting, video broadcasting, DSL, Internet access, wireless networks, DSL, power line networks and 4G/5G wireless networks for high speed data transmissions. The sophisticated transmission schemes of OFDM, used in Digital Video Broadcasting (DVB) scheme, High definition TV, Wireless LANs (Hiper LAN, IEEE 802.11a and IEEE 802.11g), Wi0Max, video broadcasting, Mobile Communication, Broad Band wireless access program as well as CDMA. The wireless LAN standard, IEEE 802.11b, uses a blend of various PSKs based on the data frequency required. At the basic frequency of one Mbits/s, it utilizes DBPSK (differential BPSK). To supply the extended frequency of two Mbits/s, DQPSK is actually used. In obtaining 5.5 Mbits/sand the full frequency of eleven Mbits/s, QPSK is actually used, but needs to be connected with complementary code keying.

1.4 Channel Estimation

The goal of channel estimation is actually estimating the frequency response of the channel which is actually prevailing when transmit antenna transmits data to the receive antenna. It is designed at the impulse effect of the channel by removing the data coming from the frequency effect. Channel estimation is actually vital for wireless uses since, in useful transmission scenario, channel correlation capabilities are often not recognized or maybe can't quickly be approximated. It's therefore appealing to possess an estimator that is powerful to mismatches between the assumed and the particular channel correlation operates. The wireless channel has fading qualities as well as the time of its changing nature provides extra expense to estimator design. The recommended channel estimation algorithm is much more powerful in phrases of model anxiety and it is a lot more appropriate for OFDM systems.

2. LITERATURE REVIEW

Chen-Hu, Kun (2020) one of the most well-known multicarrier modulation (MCM) methods is orthogonal frequency division multiplexing (OFDM). It's been utilized in a number of wideband digital communication systems, and it's the waveform of choice for 5G's New Radio (NR). We give a broad overview of this MCM in this post, detailing the OFDM signal production and related parameters. We go through some practical aspects on channel estimates, OFM variants, and their coupling with MIMO, as well as the MU operation. Finally, we go into the specifics of two different implementations of the OFDM signal in LTE and 5G NR.

Alcardo Barakabitze (2015) OFDM (orthogonal frequency division multiplexing) is a type of multicarrier transmission that sends a stream of data over a number of lower-speed subcarriers. OFDM divides the overall transmission bandwidth into a number of orthogonal and non-overlapping subcarriers, which are then used to broadcast a collection of bits known as symbols in parallel. This study provides a comprehensive overview of the different Peak-to-Average Power Reduction (PAPR) methods and OFDM system concepts utilised in wireless communications. The study report also focuses on OFDM behaviours and approaches such as Carrier Frequency Offset (CFO) estimation, which enhances OFDM performance for wireless communications. Finally, the article discusses a variety of wireless communication protocols as well as a variety of applications for OFDM systems.

Banelli, Paolo, and Rugini (2014) Orthogonal FrequencyDivision Multiplexing (OFDM) is undoubtedly the issue that has sparked and drawn the majority of research and standardisation efforts for the physical layer of digital communication systems during the previous two decades. The goal of this study is to present the subject as a natural progression from traditional single-carrier (SC) systems while maintaining intuition and linkages to the underlying physical processes. The first section of the article provides a comprehensive overview of OFDM and multicarrier (MC) communications, with a focus on the mathematical models used to describe, build signal processing methods for, and assess the performance of these systems. The second section of the paper focuses on the characteristics, benefits, and drawbacks of OFDM and MC, as well as potential solutions to fundamental signal processing problems like channel estimation and equalisation, linear precoding, transmission in nonlinear channels, time-frequency synchronisation, and bit/power loading algorithms.

Mohd Salleh, Taha, and Haitham (2009) In order to accommodate the increased demand for quality services, next-generation wireless communications systems will require faster data frequency transmission. In the recent several decades, research in wireless digital communications techniques has accelerated, resulting in more dependable wireless communication systems with improved spectral efficiency. The systems are implementing multi-carrier transmission techniques in response to the rising need for faster data frequency transmission. As a result, one of the main possibilities for future wireless systems is Orthogonal Frequency Division Multiplexing (OFDM). The purpose of this work is to offer an overview of multi-carrier transmission systems, such as OFDM and OFDM with Code Division Multiple Access (CDMA) (CDMA). The study is based on research done over the last 15 years in this rapidly expanding field of wireless communication.

Mohammad Nakhai (2008) Multicarrier transmission has lately gained popularity, especially in the field of wireless broadband access. This instructional overview article formulates multicarrier transmission from a signal processing perspective and gives an in-depth analytical grasp of the key principles that make it up. Multicarrier transmission and reception concepts are initially developed for single transmitting and receiving antenna systems, and then expanded to enable more broad and contemporary communication systems with multiple transmitting and receiving antennas.

3. PROPOSED METHODOLOGY

3.1 SECOND ORDER KALMAN FILTERING ALGORITHM

For Kalman filtering algorithms, the state area model is actually utilized for estimation, including the state model as well as the measurement model. Consider each transmission block includes K_b OFDM blocks (OBs) and Kp pilot blocks, which are uniformly placed in between the OFDM blocks. In order to exploit the status model of the foundation coefficients with the transmission block, a multipath channel is actually modelled as a BEM with Q + 1 basis coefficients over the transmission block and has L + 1 paths. From the description of the state model given, the state vector of the second-order, K = 2, is given by

$$\underline{x}[n] = \begin{bmatrix} x[n] \\ x[n-1] \end{bmatrix} \qquad (1)$$

where $x[n]$is the basis coefficient vector with the size of (L + 1)(Q + 1) by 1 at the nth transmission block, that is, $x_l[n]$ is the vector of the Q basis coefficients for the l^{th}channel path for the nth transmission block.

Consider an OFDM symbol with N subcarriers, N_{cp} cyclic prefix (CP) samples and each pilot block with the form $[0_{1\times L}\ 1\ 0_{1\times L}]$, the nth transmission block will include $M = (N + N_{cp})K_b + (2L + 1)K_p$ samples for each channel path, defined in vector form as

$$h_l[n] = \begin{bmatrix} h(n,l) \\ \vdots \\ h(n+M-1,l) \end{bmatrix} = Ex_l(n) \qquad (2)$$

where E is the basis function matrix and is defined as

$$E = \begin{bmatrix} E_0(0) & \cdots & E_0(Q) \\ E_1(0) & \cdots & E_1(Q) \\ \vdots & \ddots & \vdots \\ E_{M-1}(0) & \cdots & E_{M-1}(Q) \end{bmatrix} \qquad (2.1)$$

The state model is described by

$$\begin{bmatrix} x[n] \\ \\ x[n-1] \end{bmatrix} = \Phi \begin{bmatrix} x[n-1] \\ \\ x[n-2] \end{bmatrix} + \begin{bmatrix} I \\ \\ 0 \end{bmatrix} \mathcal{W}[n-1] \qquad (3)$$

Where Φ is the state transition matrix given by

$$\Phi = \begin{bmatrix} \Phi_{11} & \Phi_{12} \\ \Phi_{21} & \Phi_{22} \end{bmatrix} \qquad (4)$$

Where $\Phi_{ij}\ for\ i,j = 1,2$ is a block matrix. To simplify the equation, use ⊕ to specify the direct sum of matrices:

$$\boldsymbol{\bigoplus_{l=0}^{L} A_l = diag\{A_0, \dots, A_L\}} \qquad \textbf{(5)}$$

where diag is the block diagonal operator.

Therefore,

$$\Phi_{11} = -\boldsymbol{\bigoplus_{l=0}^{L} A_l[1]}$$

$$\Phi_{12} = -\boldsymbol{\bigoplus_{l=0}^{L} A_l[2]}$$

$$\Phi_{21} = -\oplus_{\boldsymbol{l=0}}^{\boldsymbol{L}} \boldsymbol{A_l}[\mathbf{3}]$$

$$\Phi_{22} = -\oplus_{\boldsymbol{l=0}}^{\boldsymbol{L}} \boldsymbol{A_l}[\mathbf{4}] \quad (\mathbf{6})$$

where I is (Q+1)×(Q+1) identity matrix, and the $A_l[i]$'s are multivariate AR coefficient matrices of the propagation path l with the size of (Q + 1) by (Q + 1), respectively. w[n] is an AWGN process with a covariance matrix Q given by

$$Q = \begin{bmatrix} Q_1 & 0 \\ 0 & 0 \end{bmatrix} \qquad (7)$$

where $\mathbf{Q}_1 = \oplus_{\boldsymbol{l=0}}^{\boldsymbol{L}} \boldsymbol{Q_{lf}}$, $\boldsymbol{Q_{lf}}$is the covariance matrix of the state vector for path l. Let σ_l^2 be the variance of the lth path. The average power of the channel is normalized to one, i.e.

$$\sum_{l=0}^{L} \sigma_l^2 = 1 \qquad (8)$$

The *A[i]* and $\boldsymbol{Q_f}$ matrices are solved using the Whittle-Wiggins-Robinson Algorithm (WWRA). From calculations of A[i] and $\boldsymbol{Q_f}$, obtain $A_l[i]$ = A[i] and $\boldsymbol{Q_l} = \sigma_l^2 \boldsymbol{Q_{lf}}$.Now the measurement model over the nth transmission block is expressed as

$$\boldsymbol{y(n)} = \boldsymbol{G[n]\underline{x}[n]} + \boldsymbol{v[n]} \qquad (\mathbf{9})$$

Where $G[n]$ is the measurement matrix and y$[n]$ is the measurement noise with every covariance

$$\boldsymbol{\sigma_v^2 = N_0/2} \qquad (\mathbf{10})$$

where $\boldsymbol{N_0}$ is power spectral density. As described the CSI is estimated based on pilot symbols which are multiplexed in the time domain. For time multiplexed pilots, the measurement model of a transmission block is given, i.e.,$\boldsymbol{y_t^P} == \boldsymbol{C^p}x + \boldsymbol{v_t^p}$, where$Y_t^p$is the received signal vector corresponding to pilot symbols, $\boldsymbol{v_t^p}$ is the AWGN vector. Therefore, for the nth transmission block, obtain $\boldsymbol{y(n)} = \boldsymbol{y_t^P}$ [n], $v[n] = v_t^p$ [n] and $G[n]$ expressed as

$$\boldsymbol{G[n]} = [\boldsymbol{C^p[n]} \quad \mathbf{0}] \qquad (\mathbf{11})$$

The measurement noise process$v[n]$ is an AWGN vector measure free of $w[n]$, and the variance matrix R[n] is a diagonal matrix with all entries on the main diagonal given by difference σ_V^2. The estimate of $\underline{x}[n]$ provides all estimations $y(n)$ to block m is indicated by $\hat{\underline{\boldsymbol{x}}}[\boldsymbol{n}|\boldsymbol{n}]$with the relating error covariance lattice meant as $\boldsymbol{P}[\boldsymbol{n}|\boldsymbol{m}]$.$\hat{\boldsymbol{y}}[\boldsymbol{n}|\boldsymbol{n}-\mathbf{1}]$ is the estimated measurement for block n, z[n] is the supposed development sequence with a covariance matrix given by $\boldsymbol{M}[\boldsymbol{n}|\boldsymbol{n}-\mathbf{1}]$and k[n] is the Kalman acquire for block n. Given an initial estimate of the state $\hat{\underline{x}}[0] = 0$ with error covarianceP$[0] = \oplus_{\boldsymbol{l=0}}^{\boldsymbol{L}} \boldsymbol{Q_l}[\mathbf{0}]$

where

$$\boldsymbol{P_l[0]} = \boldsymbol{E}\left(\begin{bmatrix} x_l[0] \\ x_l[-1] \end{bmatrix}\begin{bmatrix} x_l[0] \\ x_l[-1] \end{bmatrix}^H\right) = \begin{bmatrix} R_x(0) & R_x(1) \\ R_x(-1) & R_x(0) \end{bmatrix} \qquad (11)$$

and $R_x[i]$ is actually estimated from

$$R_h(i) = E[h_l[n+i]h_l[n]^H$$
$$= E[(\boldsymbol{E}\, x_l[n+i])(\boldsymbol{E}x_l[n]^H$$
$$= ER_x(i)E^H \qquad (11.1)$$

the Kalman filter, which is actually estimated, estimates the channel express at block n provided measurements up to y[n]. The Kalman filter is promptly altered into a Kalman smoother. The boundary estimationx_k of the Kalman filter simply consider the information in [0, k]. By and by, by including the succeeding measurements relatively tox_k, that's, the measurements including [0, n] for n > k, more refined estimation can be obtained. In the event that the radio receiver can keep the channel samples and wait until after the reception of block n prior to decoding the data symbols for block n-1, a sizable upgrade of channel estimation MSE just as, in this manner, bit error rate (BER) is really acquired. An estimation of the channel BEM coefficients $\hat{\boldsymbol{x}}[\boldsymbol{n}-\mathbf{1}|\boldsymbol{n}]$ can be determined from a sub-vector of the state vector $\underline{\hat{\boldsymbol{x}}}[\boldsymbol{n}|\boldsymbol{n}]$ from a standard Kalman filter. If the Kalman filter uses an AR model of order K ≥ 2, this does not require any more computation and the MSE of $\hat{\boldsymbol{x}}[\boldsymbol{n}-\mathbf{1}|\boldsymbol{n}]$ is less than that$\hat{\boldsymbol{x}}[\boldsymbol{n}-|\boldsymbol{n}-\mathbf{1}]$. The addtional delay is a transmission block length, which is tolerated compared to the interleaver block length. Now, the computational cost of channel estimation is analyzed. For a given SNR and f_d, Kalman filter calculation requires the inversion of the square covariance matrix of order (Q+1)(L+1) requiring $\boldsymbol{\mathcal{O}}([(\boldsymbol{Q}+\mathbf{1})(\boldsymbol{L}+\mathbf{1})]^{\mathbf{3}})$ operations. Contrasting with LMMSE estimation, it is seen that Kalman filter computation has the similar cost as the calculation of the LMMSE coefficient estimation inside one OFDM image block. By requiring the profitable asset of second request Kalman smoother, it'll be seen in Section 4.4 that the Kalman filter offers better channel estimation error to LMMSE estimation.

3.2 WIENER BOUND

For each estimation interaction, it's useful to get what the performance of the absolute best estimation procedure of that type is the sense of MSE. This might be difficult to infer for discrete time estimation procedures, especially for bandlimited processes as the optimal filter is really neither causal nor finite memory. All things considered, it's quite simple to process a bound on the estimation error for the continuous time channel estimation issue by means of standard Wiener filter standard. Estimation limits for continuous time might be changed over to the estimation limits for discrete time based on sampling theory. With this part, the MSE for the continuous time Wiener filter to estimate the radio channel is derived. Since the channel fading methodology is really bandlimited, it fulfills the Nyquist sampling theory perfectly and channel could be totally reproduced from the samples of its. In this way, there exists an infinite memory discrete time systems which may perfectly repeat the results of the continuous time channel estimation system.

In the continuous time domain, the assessed channel error is $\mathcal{E}(t) = h(t) - \hat{h}(t)$. According to the MSE of the ideal filter is

$$E[\mathcal{E}^2(t)]_{min} = \int_{-\infty}^{\infty} \frac{S_H(f)S_v(f)}{S_H(f)+S_v(f)}df \qquad (12)$$

$$\overline{N}_0 = N_0\frac{f_s}{f_p} \qquad (13)$$

where $S_H(f)$ is the Doppler power spectrum, given by Equation. $S_v(f)$ is the power spectrum of the noise, which is $\overline{N}_0$. Due to insertion of pilot symbols, $\overline{N}_0$ becomes $\overline{N}_0 = N_0\frac{f_s}{f_p}$, where N_0 is really the power density of AWGN at the input of the receiver, fs is sample rate, just as fp is really the pilot rate. Hence, the noise density $\overline{N}_0$ is really relative to fs. It is impossible to reduce $\overline{N}_0$ by including a low pass filter to remove or prevent aliasing prior to the channel estimation filter since this will destroy the time distinguishableness of the data signals and pilot symbols. In the event that maybe N0 is really fixed and considerably more pilot signals are really sent, expanding fp, the Wiener bound is lowered indicating better channel estimation is really reachable. The drawback is that bandwidth efficiency of the radio channel decreases when more pilot signals are used for channel estimations. Since the Wiener filter is really the ideal filter in expressions of MSE, the Wiener filter error gives the lower bound on the MSE for all possible pilot based channel estimation techniques for a predetermined pilot symbol density and SNR.

4. SIMULATION RESULTS

Consider an OFDM cycle with N = 128 subcarriers and N_{cp} = N/8 CP for each OFDM image. Each transmission block incorporates K_b = 10 OFDM symbols and chose Q = 4, and P = 5 pilot symbols are really brought into every transmission block. Then, simulate a one path Rayleigh fading channel with the carrier frequency fc = 3.5GHz, the sampling frequency f_s = 1.4MHz, just as the symbol duration T = 91.4µs. The framework is intended for velocities v = 168.8km/h and v = 337.6km/h, which lead to f_dT = 0.05 and f_dT = 0.1, separately. The DPS-BEM' and Oversampled CE-BEM' are really the outcomes by utilizing LS estimators to do channel estimation relying upon the discrete prolate spheroidal BEM (DPS-BEM) and oversampled muddled dramatic BEM (CE-BEM), individually. The 'KL-BEM' is the outcomes where we use MMSE estimator to do channel estimation dependent on Karhunen-Lo'eve BEM (KL-BEM). The MSE consequences of the direct estimation are displayed in Figure 2.1 for f_dT = 0.05. The Wiener bound is determined from Equation. observed that Kalman channel estimation betters MSE proficiency. The small gap between the Wiener bound just as the Kalman smoother shows that the Kalman smoother further develops the MSE proficiency impressively and offers near optimal performance.

In BER simulation, a DFE with MMSE is used, where the ICI power on a subcarrier comes from various adjoining subcarriers. In the simulation, the ICI power for each subcarrier focuses on two adjoining subcarriers is assumed. Quaternary phase shift keying (QPSK) modulation is really used for BER simulation. The BER results for channel estimations are really displayed in Figure 2.2 for f_dT = 0.05. The 'Perfect CSI' is the resultant BER for the known CSI at the receiver, and the simulated BERs for various channel estimators are displayed in these figures. The outcomes show that both Kalman filter and smoother can further develop the BER execution contrasted with past channel estimation techniques. It very well may be seen that for f_dT = 0.1 and E_b/N_0 around 30 dB the Kalman smoother gives an improvement of around 1 dB for BER execution than the utilization of BEM channel estimation alone.

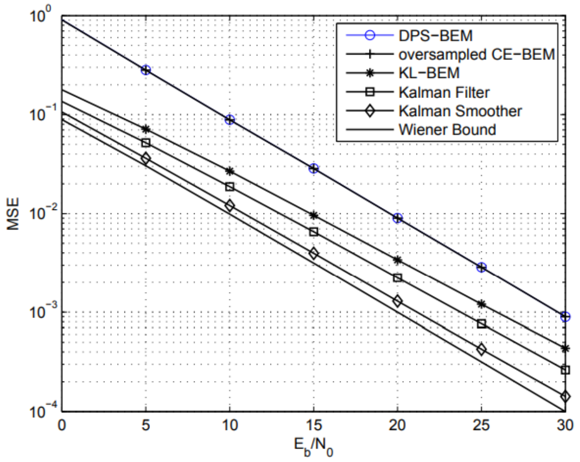

Figure 2.1: Channel estimation MSE for

f_dT = 0.05

The new Kalman channel estimation is actually powerful once the designed f_dT or maybe SNR used to produce the powerful model as well as measurement model equations for Kalman filter equations aren't same as true values. Simulation results are actually revealed in Figure 4.3 for the designed $f_dT = 0.05$ when SNR = 10dB. Here, observed that when the assumed f_dT is actually lower compared to the true value, Kalman channel estimation still is effective. Once the assumed f_dT is actually greater compared to the true value, the suggested strategy will fail. In the event that thisalgorithm is used in a radio receiver, a conservative design choice would be to set the assumed Doppler frequency of the Kalman smoother to the highest expected level.

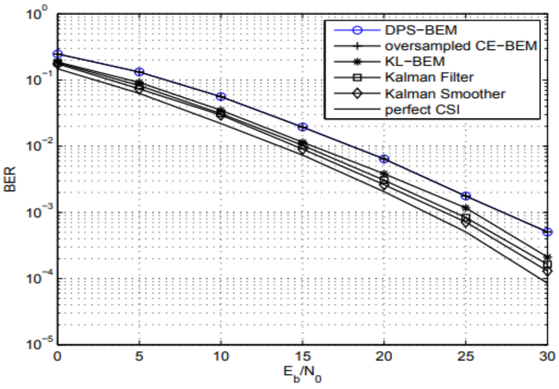

Figure 2.2: Channel estimation BER for f_dT = 0.05

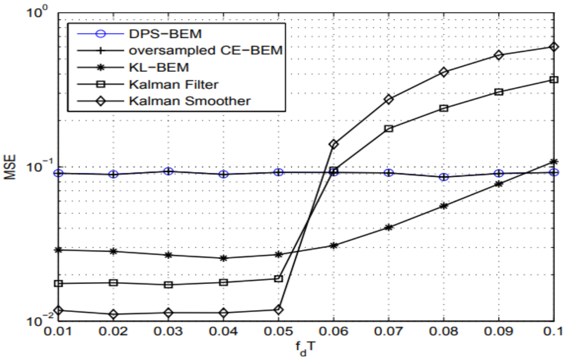

Figure 2.3: Channel MSE for SNR = 10 dB and designed f_dT = 0.05

5. CONCLUSION

In this paper, a time evolution model for basis coefficients in fast fading radio channels is actually introduced. This particular model allows channel state information assessed in adjacent time intervals to be combined together to enhance the complete channel estimation accuracy. A Kalman filter algorithm depending on the derived dynamic model for basis coefficients was introduced in this specific chapter. Simulation results show that Kalman filter/smoother improves the BER and MSE performance.

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